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Improving Reproducibility in Sputtered Beryllium and Graded Copper Doped Beryllium Capsules

K. Youngblood, J. Hayes, K. Moreno, A. Nikoo, H. Xu, C. Alford, S. Bhandarkar

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Disclaimer

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K. Youngblood, J. Hayes, K. Moreno, A. Nikroo, H. Xu
General Atomics, PO Box 85608, San Diego, CA

C. Alford, S. Bhandarkar, Lawrence Livermore National Laboratory, Po Box 808, Livermore, CA

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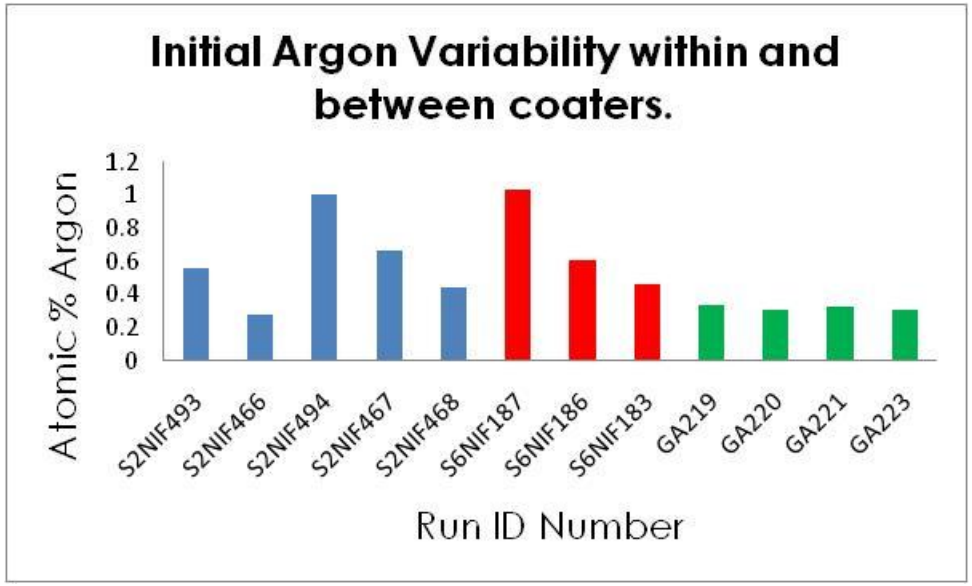
GENERAL ATOMICS

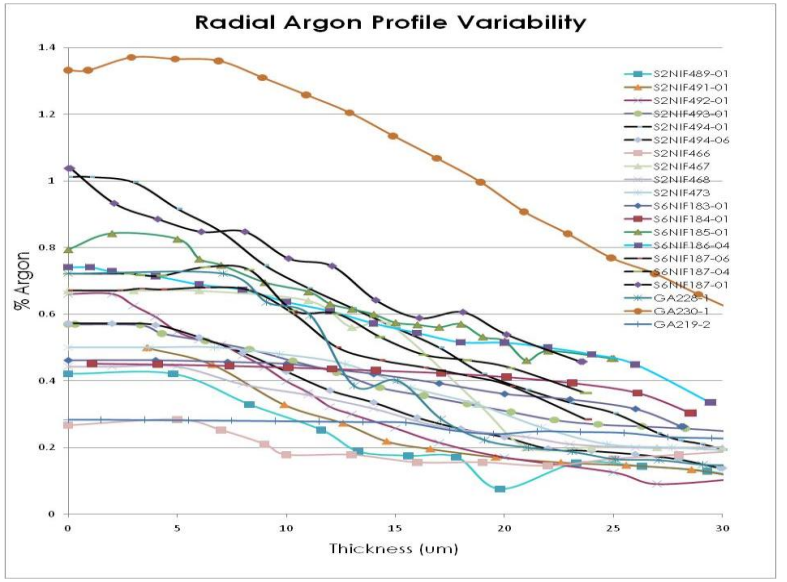
One of the designs for the NIF ignition targets is a Graded Copper Doped Beryllium Capsule

- **Several magnetron sputtering systems are dedicated to producing these capsules**
  - These systems are located at General Atomics in San Diego and at Lawrence Livermore National Laboratory in Livermore
  - The systems were all assembled at different times with varied gun components, chambers, and configurations
- **We needed to minimize the natural variations in coating properties from system to system**

The argon variation within and between the systems needed to be reduced

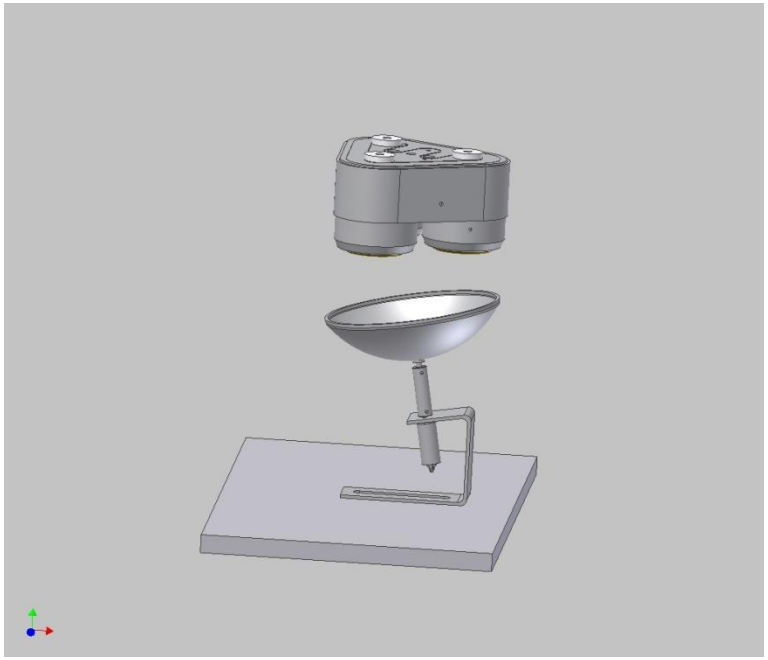
- The atomic percent of argon varied from run to run and from coater to coater
- The radial argon profile also varied





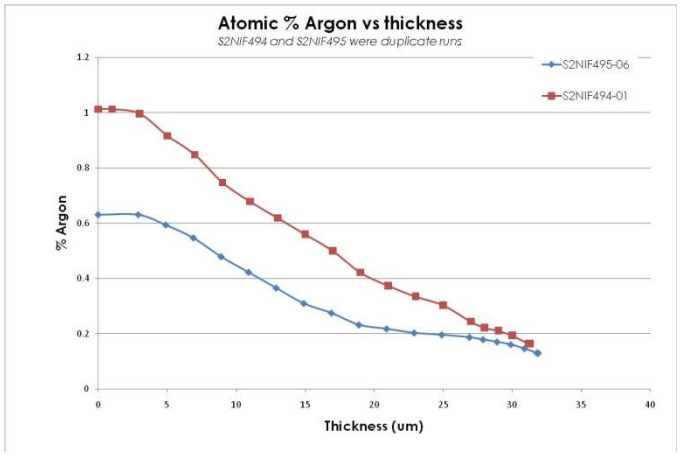
The coating system with the highest yield of target quality capsules was evaluated

- **We wanted to improve the reproducibility of the S2 system and duplicate those results in the other coaters**
  - Careful measurements of the system were taken
  - Hard stops and other positioners were designed and installed to decrease run-to-run variability

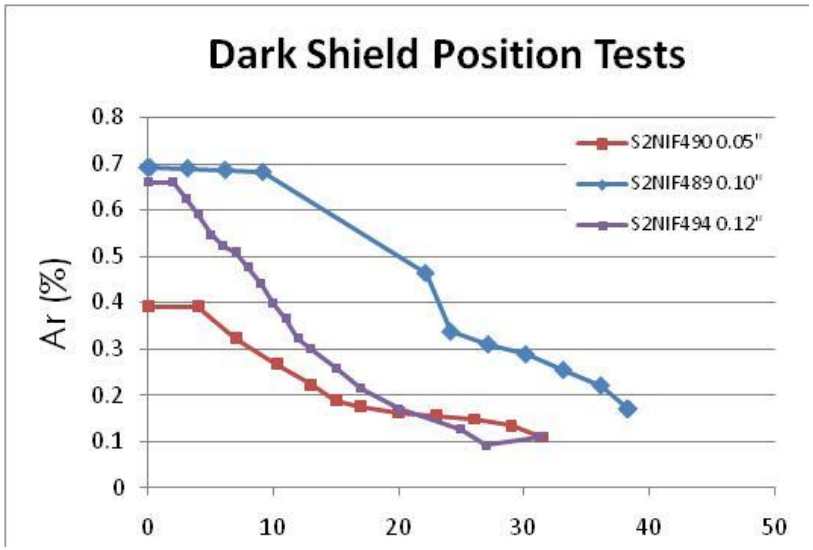


Even after engineering, argon results were still varied and did not correlate with changes

- **We designed a simple experimental matrix**
  - Changed one parameter slightly (ie, gun to pan distance)
    - Results were not reproducible
    - Trends were not evident



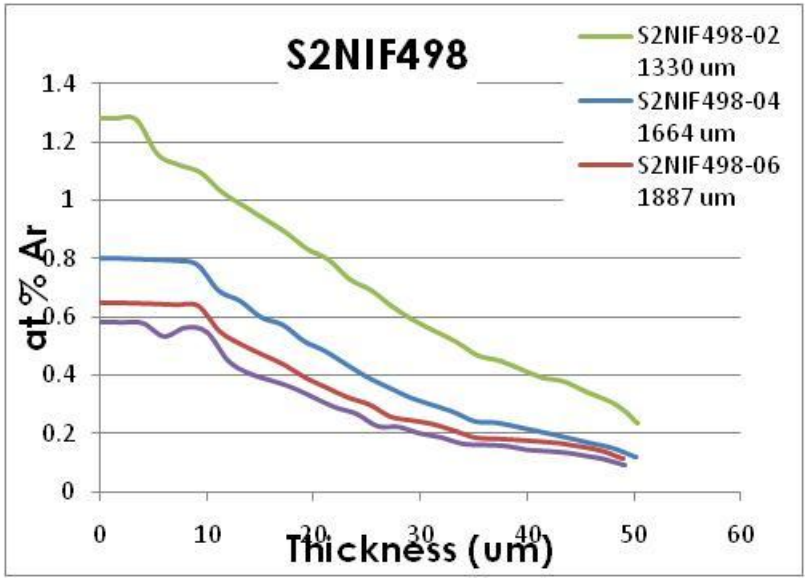
We did not see identical argon results when run conditions were duplicated

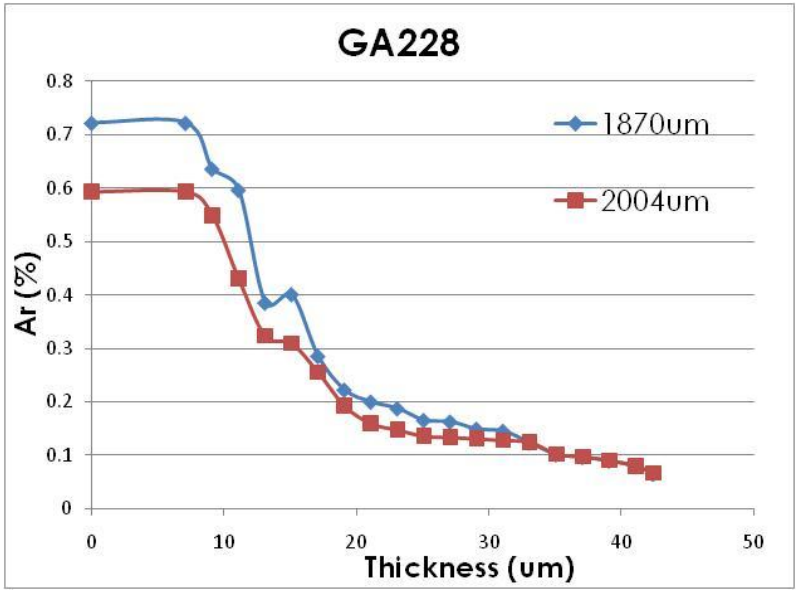


Stepped variations did not indicate any trends

A run with more than one sized mandrel was completed

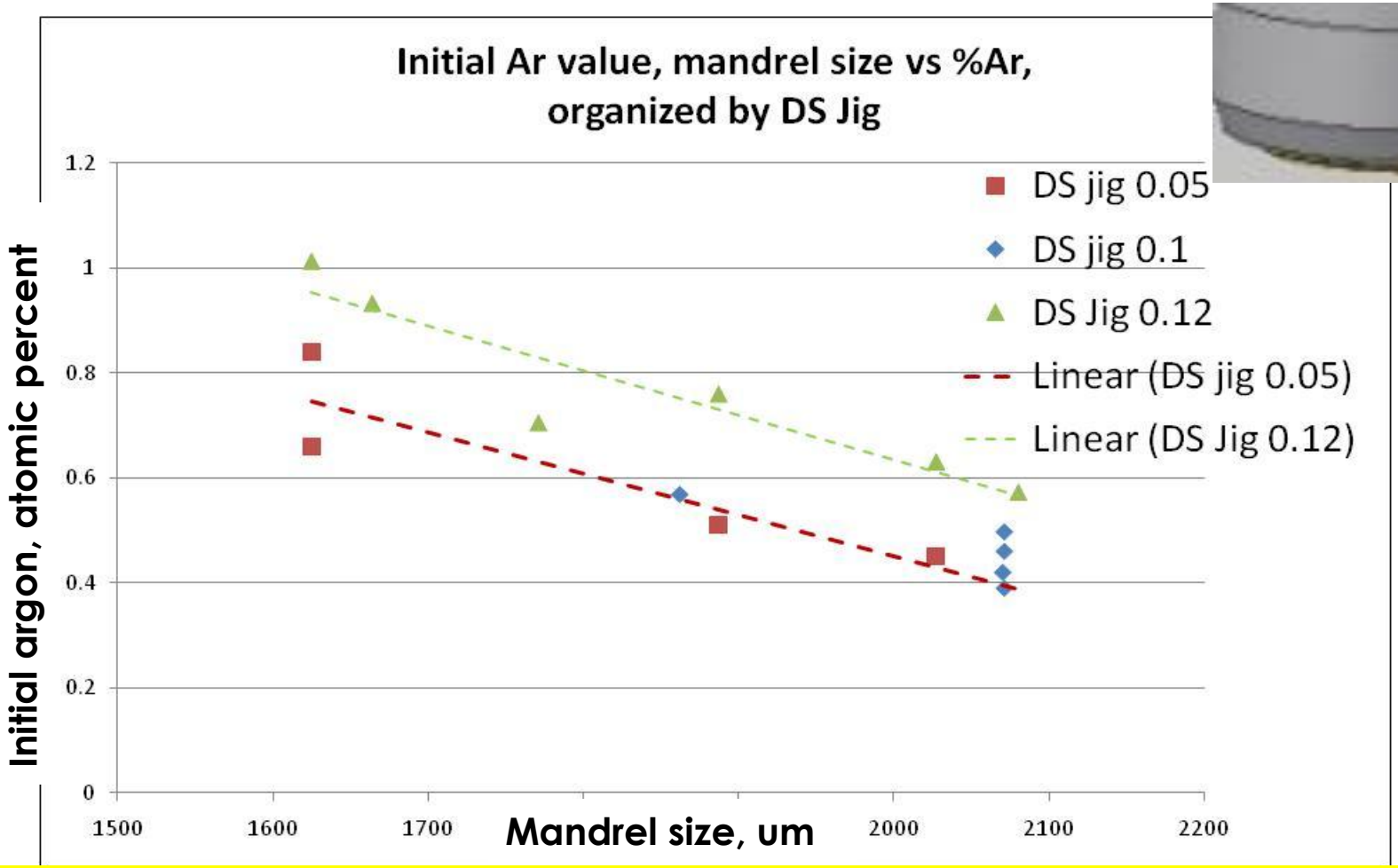
- **Different profiles were observed and were related to mandrel size**
  - This holds true in all 3 coater systems





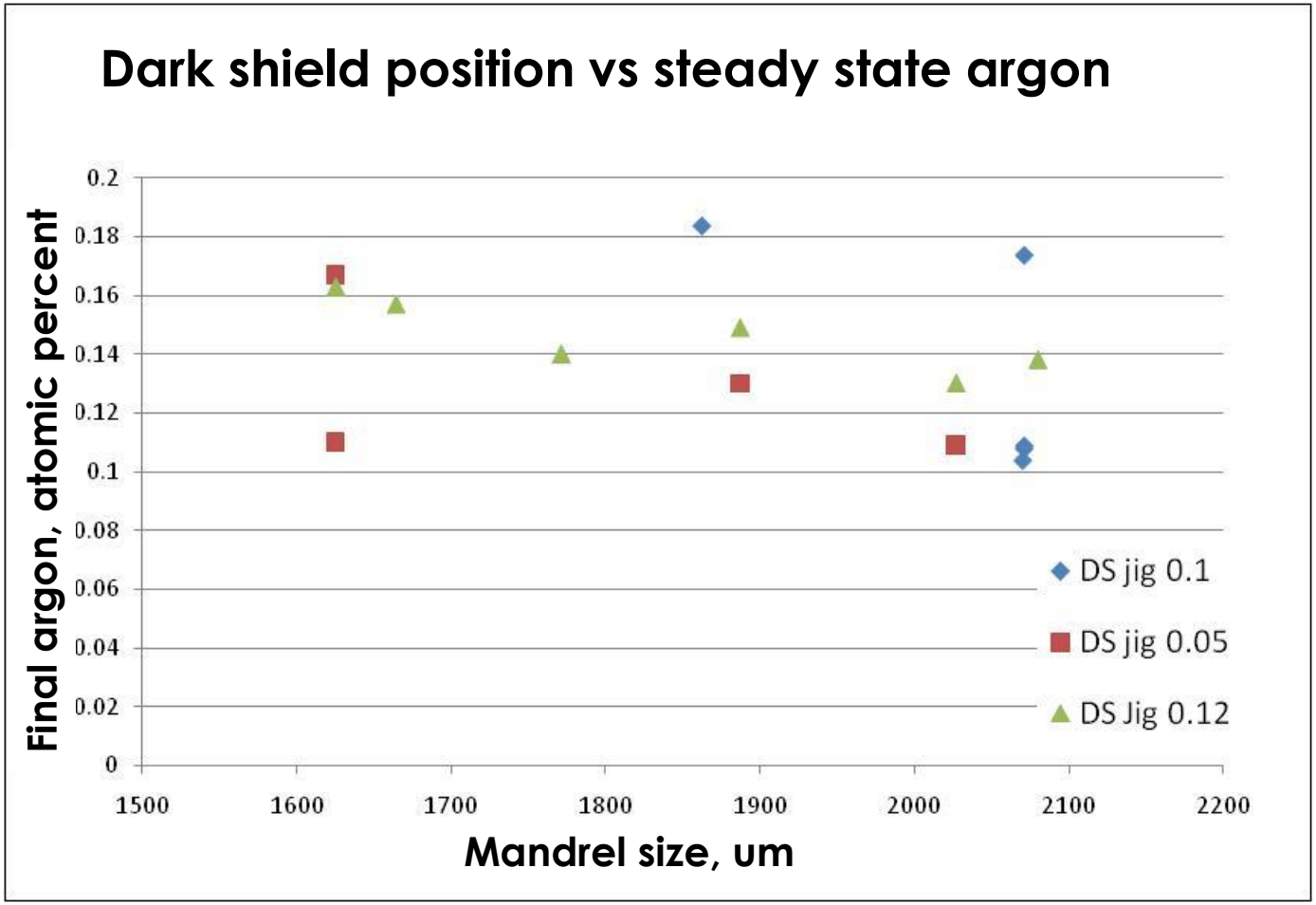
The smaller the mandrel, the higher the initial Argon; but the steady state Ar value stayed the same

Darkshield Position Optimization



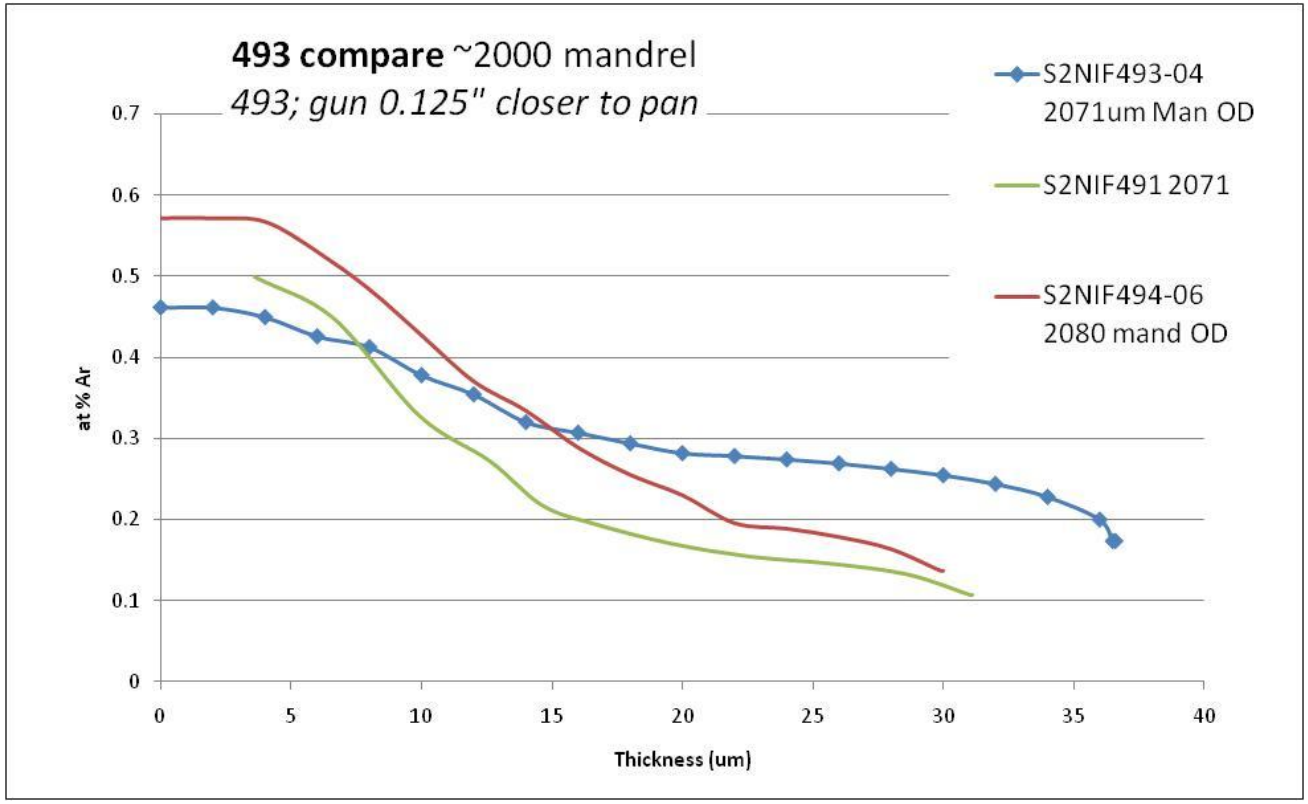
The smallest darkshield-to-target gap results in the lowest initial argon.

Darkshield Position Optimization



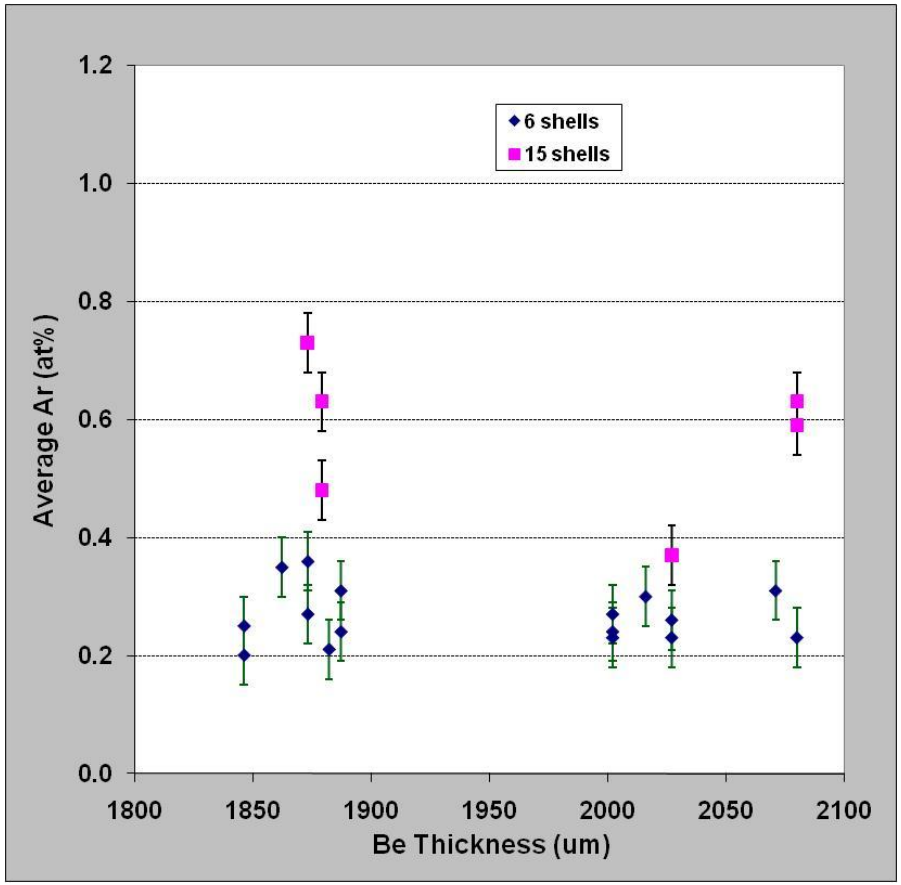
***Final* Ar values are not affected by the darkshield position.**

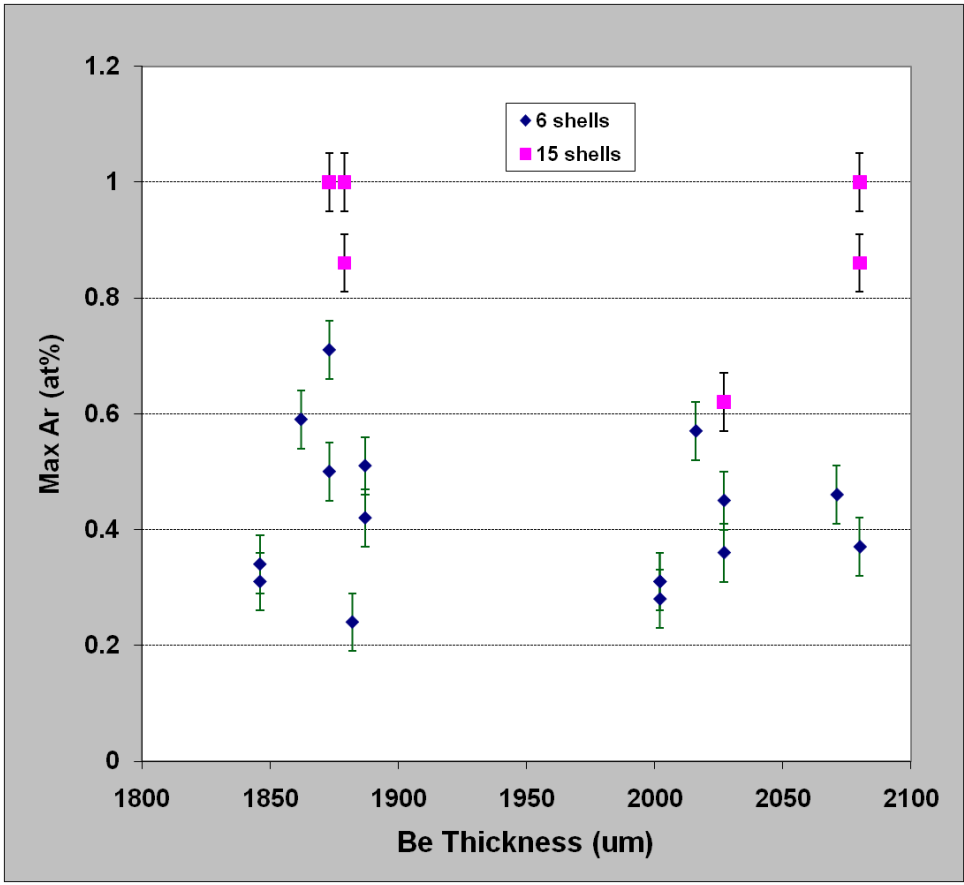
Gun-to-pan distance optimization



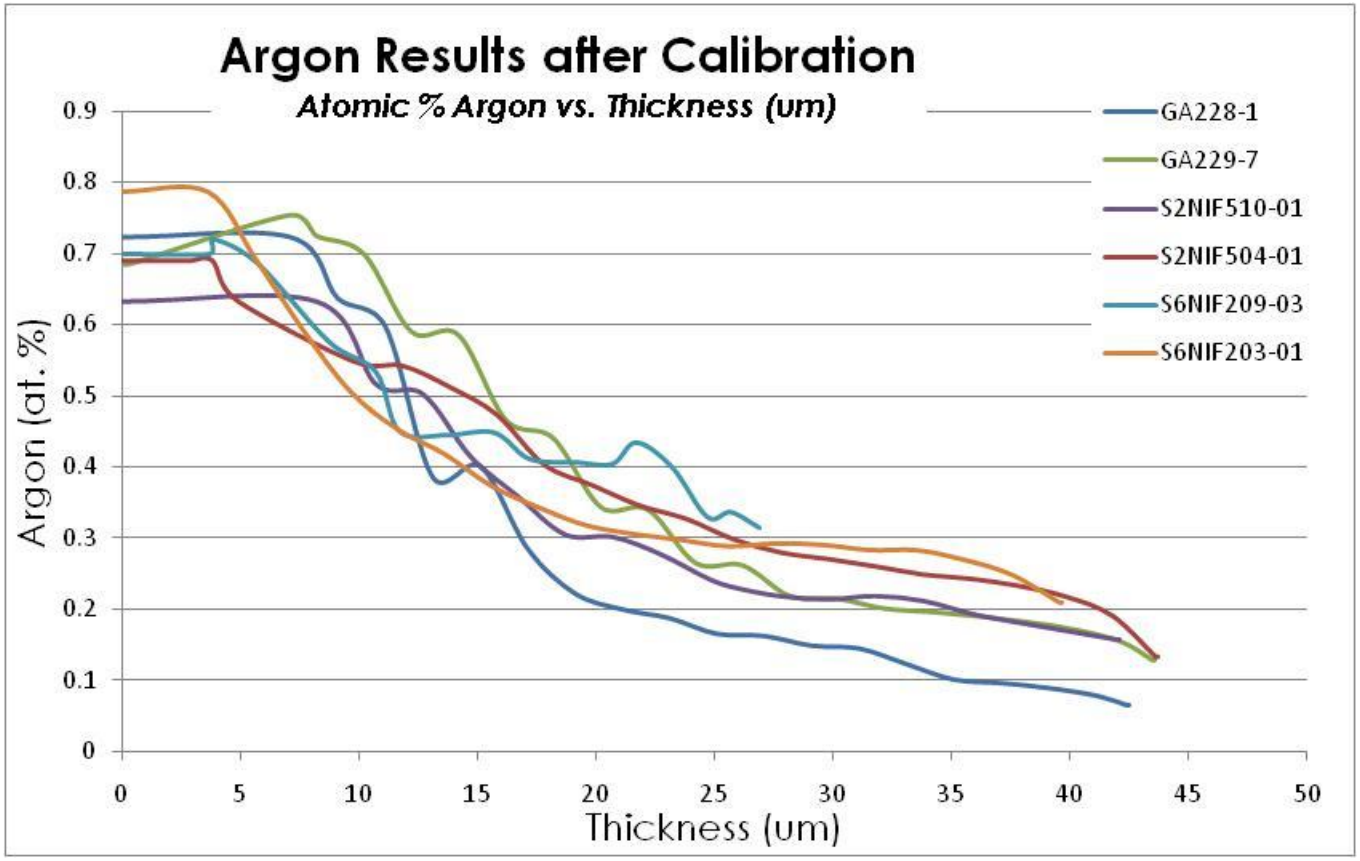
- **Steady state argon increased as the distance from the gun to the pan decreased.**

Increased mandrel quantity increases the Ar concentration

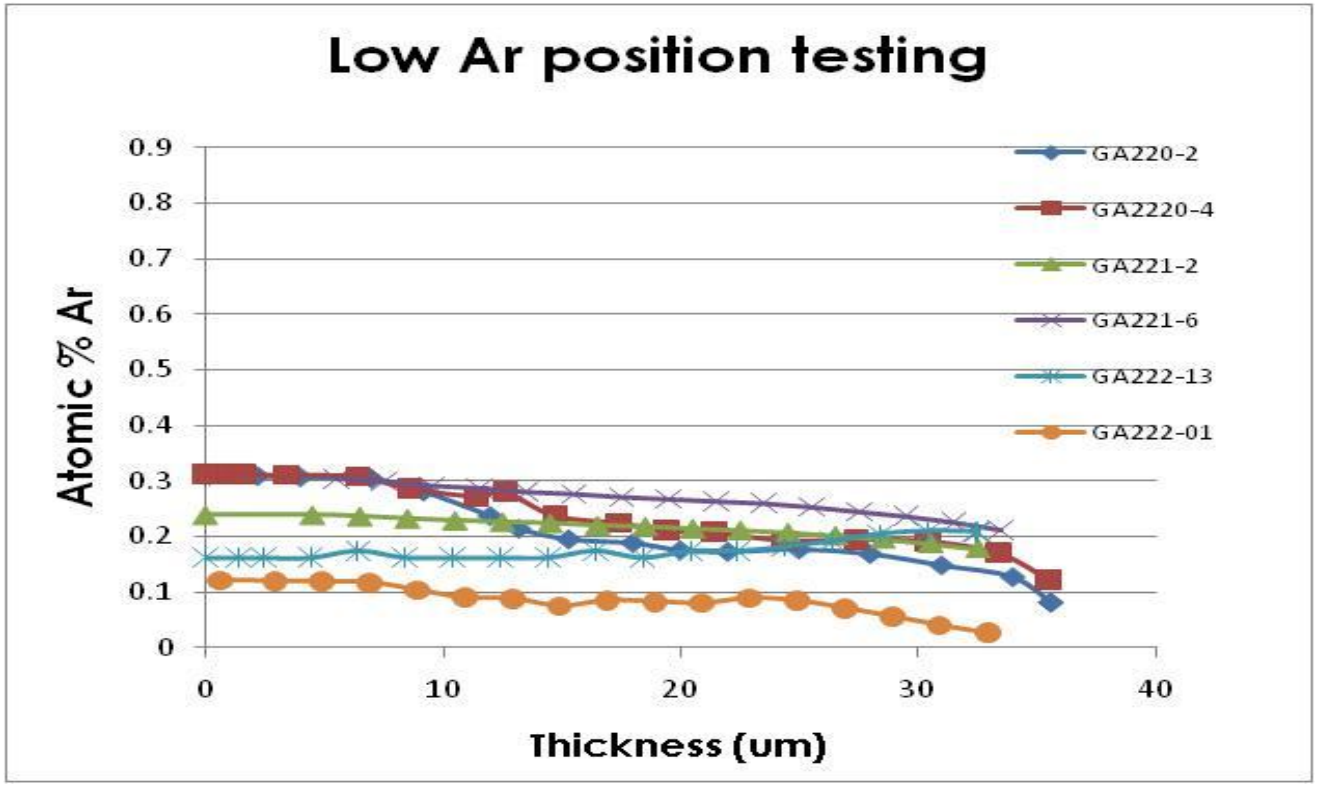




After careful alignment, argon profiles were reproducible and consistent



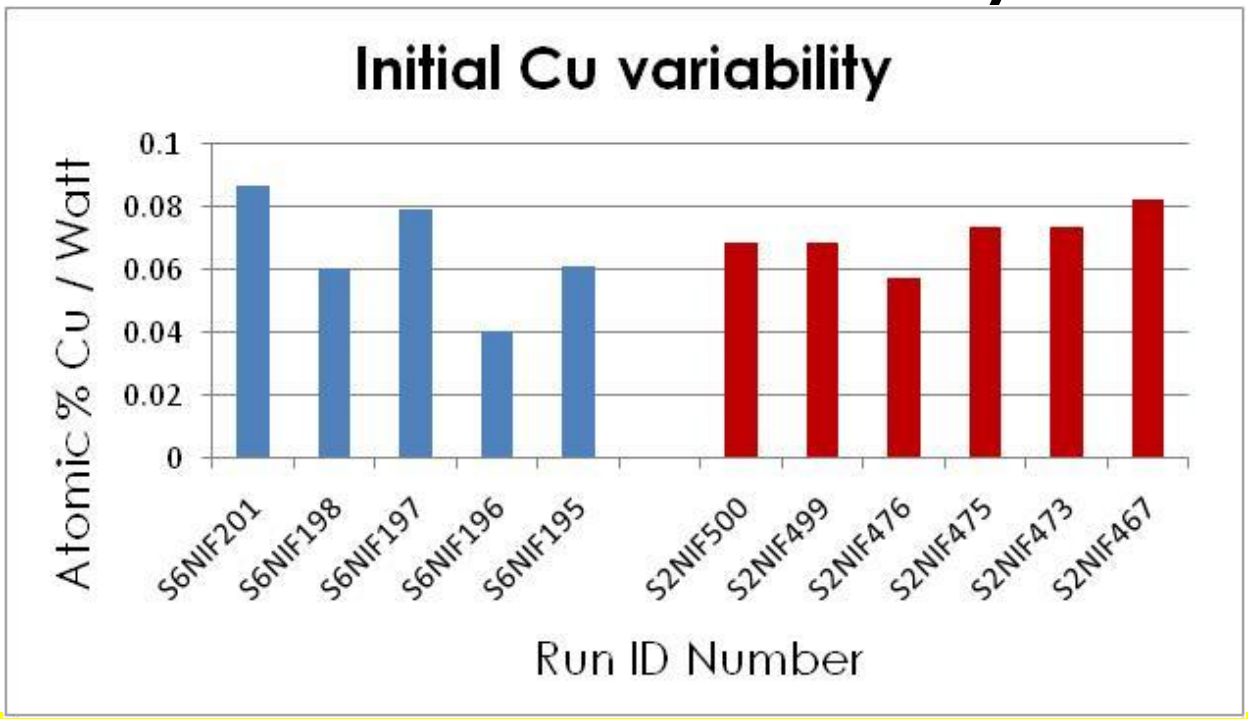
An additional change may result in lower argon



- **Lower argon concentration will increase the likelihood of ignition**

The copper coating rate fluctuated

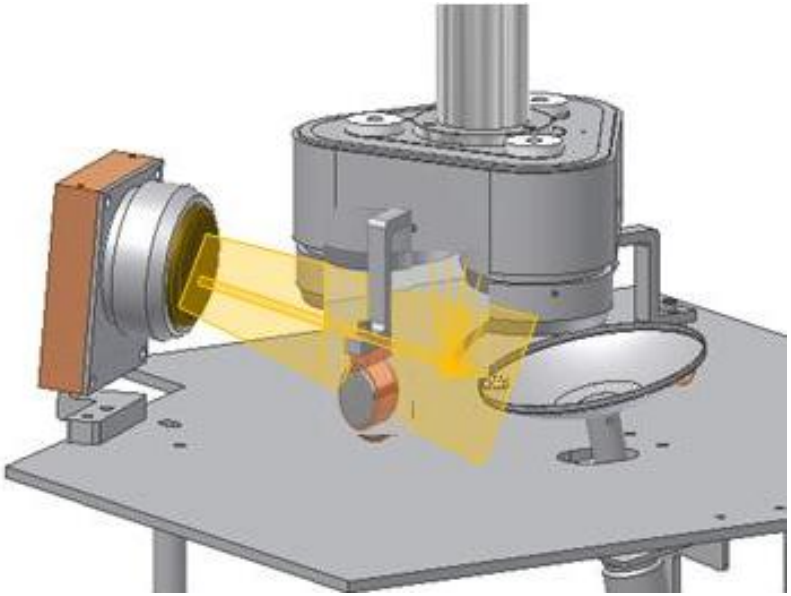
- **The point design requirements could not be met without recalibration for every run**

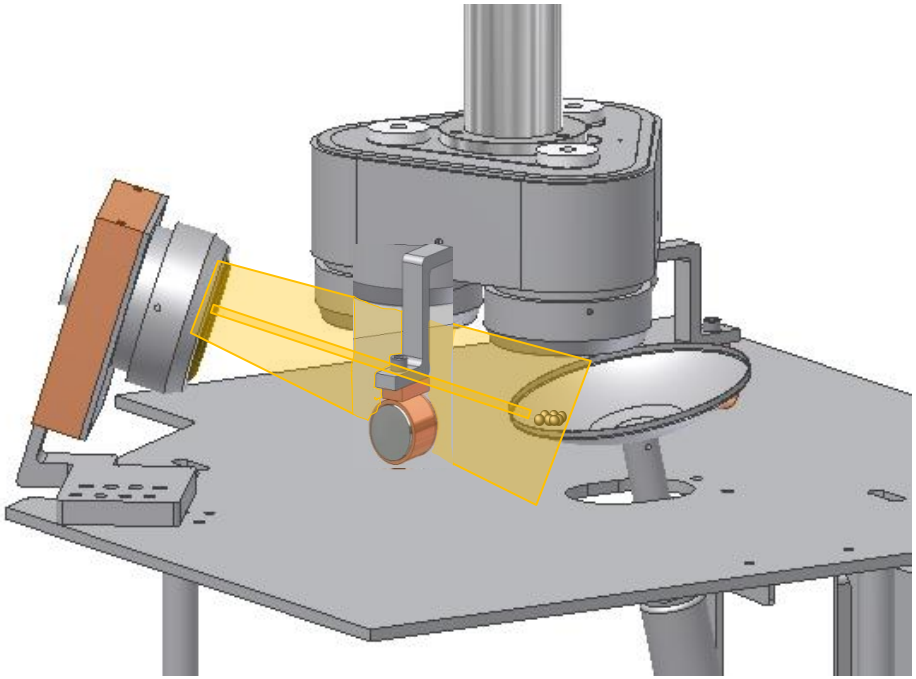


- **We needed to optimize our process to improve reproducibility**

We optimized the position of the copper gun

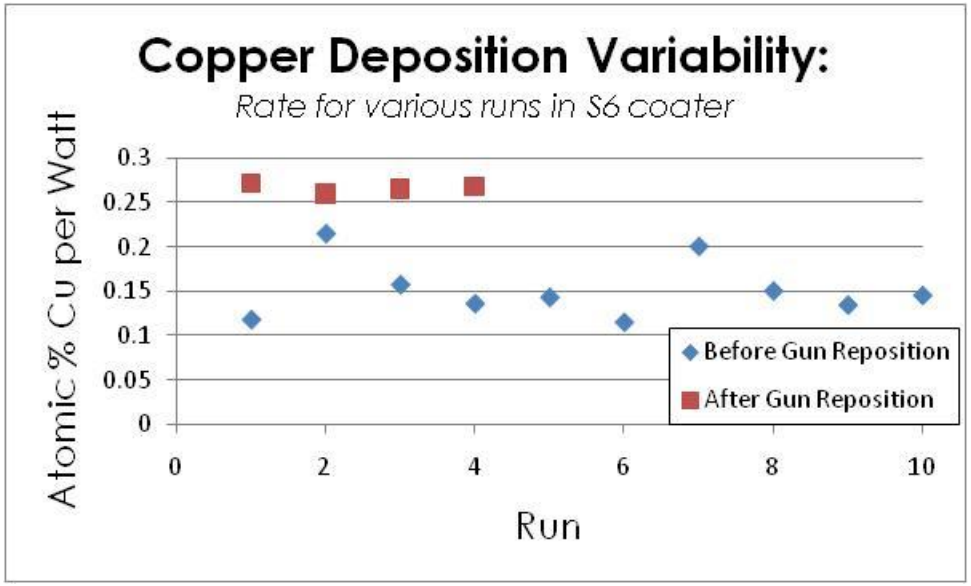
- **The copper gun was repositioned to minimize any shadowing**





Copper deposition rates stabilized

- **Rates were consistent within each coater, but not from coater to coater**
  - We were not able to standardize gun position due to chamber configuration restraints



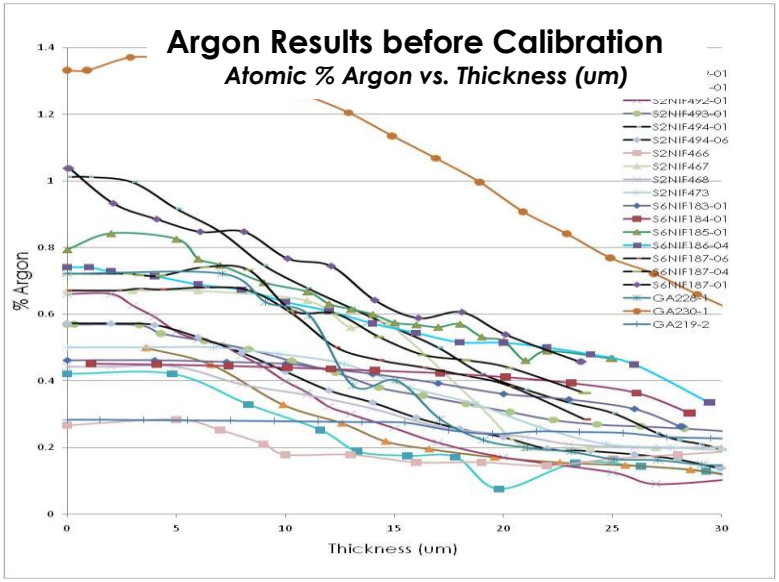
Coaters all demonstrate nonlinearity between copper wattage and deposition rate

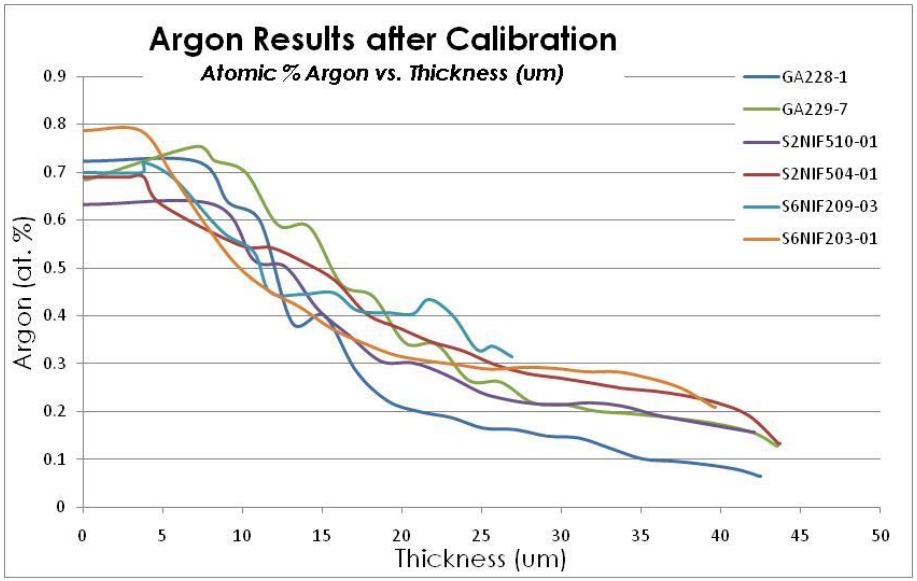
- **Expect to see linearity between watts and at % Cu**
  - Three times the power should equal three times the concentration
- **All coaters show the same deviation**
  - To increase from 0.5 to 1.5 atomic % Cu, it is necessary to apply 3.6 times more power

Cu Goal	0.5 at %	1.5 at %	
	Watts 1	Watts 2	W2/W1
GA Coater	7.0	25.5	3.64
S2 Coater	2.0	7.3	3.60
S6 Coater	3.4	12.4	3.66

Summary of Argon optimization

- **We were able to reduce the run to run and system to system variability of the argon profile with careful calibration of the coating systems**





Summary of Copper optimization

- **Two of the coaters have been tested and routinely meet specifications**

Date	Run Number	Cu Goal	Cu Actual	In Spec?
7/17/2009	S2NIF504	0.5	0.51	YES
7/17/2009	S2NIF504	1.0	1.03	YES
7/22/2009	S2NIF505	0.5	0.39	YES
8/4/2009	S2NIF508	0.5	0.5	YES
8/4/2009	S2NIF508	1.0	1.2	YES
8/11/2009	S2NIF509	0.5	0.5	YES
9/2/2009	S2NIF512	0.5	0.5	YES
9/2/2009	S2NIF512	1.5	1.2	LOW
9/9/2009	S2NIF513	0.5	0.5	YES
7/24/2009	S6NIF197	0.5	0.5	YES
7/24/2009	S6NIF197	1.5	1.39	YES
7/29/2009	S6NIF198	0.5	0.38	YES
8/14/2009	S6NIF201	0.5	0.52	YES
8/14/2009	S6NIF201	1.5	1.36	YES
8/19/2009	S6NIF202	0.5	0.45	YES
Break for aperture adjustment				
10/23/2009	S6NIF210	0.6	0.8	YES
10/23/2009	S6NIF210	1.5	1.6	YES
10/28/2009	S6NIF211	0.6	0.8	YES

Further Production Goals

- We plan to modify the coater configuration to reduce the argon concentration
- We will re-optimize the copper for all systems as we finish the argon modifications